Study Reliability Centered Maintenance (RCM) of Rotating Equipment through Predictive Maintenance

Mariam Altaf Tarar

Abstract—Reliability Centered Maintenance (RCM) is the structured framework of preserving equipment functions, rather than preserving physical asset. RCM is used to formulate planned maintenance program that will ensure availability of equipment with both reliability and maintainability. This paper presents XYZ Company case, where maintenance can be properly planned while focusing mainly reliability factor of equipment function. It is possible with implementation of Reliability Centered Maintenance, which enables to take maintenance action on basis of decision made with evidence and reduce maintenance staff unnecessary actions.

The XYZ Company maintenance strategy is preventive maintenance. This preventive maintenance may supported by manually collected data of any parameter to trace machine health and condition. Usually this data indicates abnormality after appearance of failure. This paper evaluates effectiveness of existing maintenance strategy with improvement proposals. It shows RCM process and a case study of paint booth fans process.

The paper reveals that the successful RCM implementation in any industry can ensure better performance to take competitive advantage in global market.

Keywords—RCM, Rotating Equipment.

I. BACKGROUND

MAINTENANCE is routine recurring effort, which is needed to preserve equipment in a state in which equipment can perform its intended function. In order to compete in global market, industries must focus all performance disciplines and to ensure machine availability maintenance department got importance and enhancing capabilities and strategy. Like all other management disciplines, maintenance has also entirely changed during the past twenty years. In early ages, the breakdown maintenance was commonly practiced, because there was no downtime awareness. But complexity of machines led to the prevention maintenance in second generation, and then objectives and strategies of maintenance have rapidly changed from preventive maintenance to predictive maintenance. In recent era, the significance of effectiveness of operational equipment raised, which is related to plant capacity (Raouf, 2004). So, the concluded maintenance strategy requires balance between reliability of plant and cost of maintenance. In Pakistan industries usually preventive maintenance strategy or scheduled maintenance is followed. According to Herbaty, to prevent equipment from breakdowns periodic actions are performed at predetermined time interval in preventive maintenance or, to keep it in proper working condition these periodic actions performed after the specified extent of equipment usage (Herbaty, 1990). In 1960s, a new concept of Reliability Centered Maintenance (RCM) developed. In the beginning RCM was used in aircraft industries, and it was adapted towards jets maintenance (Dekker, 1996). RCM is a framework and a logical method of optimizing resources of maintenance not only for physical asset’s maintenance but also in its operating context to preserve function. RCM examines the equipment functions, potential failures, risk associated with the failure and its seven-review step philosophy is helpful to evaluate “inherent reliability”. With help of RCM it is possible to select an effective maintenance strategy that will offer “inherent reliability” of equipment (Samanta et al., 2001).

II. OBJECTIVE

The main objective of this research is to study Reliability Centered Maintenance strategy and the benefits of its implementation for the equipment at XYZ Company. This paper evaluates pitfalls of XYZ Company existing maintenance strategy, and its improvement proposal through RCM framework. So, the RCM analysis will provide the optimum maintenance strategy and proper time to plan and perform maintenance action before failure occurs. It will facilitate maintenance staff in decision making by providing evidence.

III. METHODOLOGY

The research methodology is qualitative and to collect data primary data sources are used. The method of data collection is observation which is non-participant and structured interviewing of maintenance staff of XYZ Company. The case study primarily describes existing situation and problems facing with this existing preventive maintenance strategy because of the different opinions of people about an issue and having different observations based on individuals experience and skill, and usually have variation. So the data is collected, and analyzed to improve this situation.
IV. EXISTING PREVENTIVE MAINTENANCE AND ANALYSIS

The critical equipment in existing situation is monitored on basis of manual observation of staff on duty and data collected by them on daily basis. With this method of monitoring parameters, it is very difficult to predict failure accurately on the basis of manual data collected by hearing or visualizing equipment. The pitfalls of this method are given below;

1. This observation based data is not indicating any boundary limit of each parameter.
2. This method identifies abnormality when actually failure occurs and left marks of failures.
3. It enables to alarm imminent failure and reduce the chances to take remedial action before failure occurs.
4. The daily monitoring every 3 hours that requires extra manpower to check and handle this manually collected inappropriate data, which is on the basis of senses of sight, smell, touch and hearing.
5. Unneeded preventive maintenance task performed to just fulfill schedule requirement. No proper health monitoring of equipment.

Proposed Maintenance Action Plan:

• Classify and selecting equipment for maintenance,
• RCM Process Seven Questions & Answers,
• Select RCM strategy.

Classify equipment for maintenance

First of all it is required to classify all equipment for selecting appropriate maintenance type according to requirement. The two methods used to select equipment are Criticality Analysis and Selection Question method that is usually employed.

The car paint process is important not only in aesthetic aspects of car but also it has direct impact on the business. Car Paint quality cannot be compromised because it is an integral feature of a business to generate repeated sales. The purpose of paint is to get smooth, uniform and shiny coats which can withstand extreme conditions of sunlight, rain or dust and tends to last long. So the paint booth process plays vital role to fulfill all requirements of finishing process, as given below.

- Shiny and glamorous look,
- corrosion and rust prevention,
- Resistant to fading due to sun and ultraviolet rays,

In process of Painting and Drying Spray booth plays an important role where the selected critical components are fans. In Painting and Drying Spray booth the vehicle is painted through a spray gun with air channel, which works under low pressure, followed by drying. The ceiling filter system derives air from outside of the facility, into the booth. Paint stop filters hold paint particles which are decomposed from air. Spray booth contains diesel burner and fan-motor units. A channel connection to units for air circulation is executed and installed on the facility floor.

The most important and critical function of a spray booth is managing its airflow maintaining uniform velocity in unidirectional layers. The managed airflow results in two advantages,

- Maximum efficiency of the paint sprayed in the Paint booth,
- And improved finish quality through directing overspray away from the painted finish.

Air supply house supplies air to the booth after conditioning and filtering, minimizing temperature variations and removing particulates that compromise finish quality.

Intake air moving across the painting operation conveys the overspray into the water curtain and the water wash apparatus, which then works to move the water in such a way as to trap and separate the particulate from the recycling water.

Process flow of paint booth is shown in fig 5, with sequence of operation and sequence of equipment.

Step # 1 Equipment Selection
Step #2 RCM Process Seven Questions & Answers:

1. What are the functions and associated desired standards of performance of the asset in its present operating context (functions)?

Delivery of air into the booth or circulation of it is provided by fans, having the capacity of 360 m³/min. In this unit air is delivered to the booth after being filtered by a pre-filter. Additionally, output air is controlled by a damper in the output air channel.

1. In what ways can it fail to fulfill its functions (functional failures)?

<table>
<thead>
<tr>
<th>Function</th>
<th>Function Failure</th>
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</thead>
<tbody>
<tr>
<td>Delivery of the air into the booth or circulation of it is provided by fans while meeting all quality, health, safety, and environmental standards.</td>
<td>1. Unable to rotate at 1460 rpm</td>
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<tr>
<td></td>
<td>2. Unable to meet quality standards</td>
</tr>
<tr>
<td></td>
<td>3. Unable to meet health, safety, and environmental standards.</td>
</tr>
</tbody>
</table>

2. What causes each functional failure (failure modes)?

Vibration is due to the repeating forces in machines which are mostly due to the rotation of imbalanced and misaligned parts and may be due to the following,

- Looseness
- Contamination
- Oil condition
- Wear and tear
- Defective bearing

3. What happens when each failure occurs (failure effects)?

Failure may have following effects;

- Broken, deformed, corroded or dirty fan blades.
- Fan may trip
- Machine unavailability
- Unnecessary maintenance at predetermined schedules to adjust and replace parts regardless of whether or not the machines are malfunctioning
- **Quality problems** when machine is running, which apparently seem functioning normally, but actually running into trouble and may have yielded losses rework costs, or worse still, warranty returns by customers.

4. In what way does each failure matter (failure consequences)?

Failure may have following effects;
• High Power Consumption, as machine that is vibrating consumes more power.
• Cost of lost production
• Cost of emergency spares procurement
• Cost of maintenance and additional overheads
• Delayed Shipment resulting in customer dissatisfaction
• Accumulation of unfinished goods or WIP(work in process)
• Bad company image will be associated with shipment delays and poor quality
• Occupational hazards and human discomfort

5. What should be done to predict or prevent each failure (proactive tasks and task intervals)?

Monitoring the vibration characteristics of a machine gives us an understanding of the ‘health’ condition of the machine. We can use this information to detect problems that might be developing. Operating a machine until it breaks down might be acceptable if the machine was a ‘disposable’ one. Most machines, however, are not ‘disposable’ due to their cost.

6. What should be done if a suitable proactive task cannot be found (default actions)?

Default actions are may be routine preventive maintenance at predetermined schedules and cleaning of fan blades or allowed to breakdown.

This RCM seven Question process helps to determine the causes of system failures and develop activities targeted to prevent them. The questions are designed to focus on maintaining the required functions of the system and help to conclude proactive maintenance strategy.

The answers of first four questions, which are related to functional failure, causes and effects, are recorded in RCM information sheet as shown in table 4.

In table 5 answers of remaining question is recorded which is decision worksheet. Decision worksheet is recorded with the help of answering question in RCM decision diagram related to failure consequences, preventive tasks and default actions as shown in Fig 6.

<table>
<thead>
<tr>
<th>TABLE IV</th>
<th>RCM INFORMATION WORKSHEET</th>
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<tr>
<td>Sr. no</td>
<td>Function</td>
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<td></td>
<td>Functional failure</td>
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<tr>
<td>1</td>
<td>Delivery of the air into the booth or circulation of it is provided by fans while meeting all quality, health, safety, and environmental standards.</td>
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<th>TABLE V</th>
<th>RCM DECISION WORKSHEET</th>
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<td>Information reference</td>
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<td>(e)</td>
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Step # 3 Selecting RCM Strategy:

In process of paint booth, unscheduled breakdown of critical components like fans can cause production and other consequential losses. One of the selected critical components is fans, in which buff deposit may cause other defects like wear, imbalance, etc. Its managed airflow enables to get maximum efficiency of the paint sprayed while directing overspray away from the painted finish. Predictive maintenance through vibration monitoring is selected to keep the function preserved. The parameter of velocity is selected to monitor such that must it be evenly maintained and balanced at 0.5mm/sec to perform proper function.
The data collected (Table 6 and Fig 9) is plotted in given below graph, and analysis performed on these reading revealed operation at alarm level.

![TREND DATA](image)

**Fig 9 Equipment Vibration Monitoring Trend report before repair**

After trend analysis for default detection, it is found that;

- buff deposits on fan blades,
- unbalancing,
- bearings in deteriorated condition and,
- oil condition has to be inspected,

So far, the remedial action of cleaning has been performed to remove buff deposits from blades and deteriorated bearings were replaced. Fan was then rotated and found dynamic unbalanced, so in-situ balancing performed to restore proper functioning. It is dynamically balanced at 1460 rpm and the vibration level reduced from 0.61 mm/sec to 0.5 mm/sec, as shown in graph (Table 7 and Fig 10) below.

![TREND DATA](image)

**Fig. 10 Equipment Vibration Monitoring Trend report after repair**

In this way, vibration monitoring data provided very detailed assessment of fault causes, and selected repair action performed as per need of equipment condition. Since then, the fans are running smoothly and uninterruptedly.

V. CONCLUSIONS AND PERSPECTIVES

To preserve equipment function, RCM seven question analyses performed in case study and predictive maintenance selected on basis of RCM analysis instead of preventive maintenance to identify causes of imminent damage. So, it benefits in two ways by repairing equipment before failure and increase reliability by eliminating root causes. In this way, RCM helps to plan scheduled maintenance when required, and scarce economic resources on critical equipment having high risk of failure. The paper reveals that the XYZ Company can achieve enhanced production and quality leading to competitive advantage with successful RCM implementation through selecting appropriate maintenance strategy.

Due to limited resources and time, the paper showed only test case of fan of paint booth, but in case it will implemented on all critical equipment then it will further clarify the differences and benefits of RCM. So, it is strongly recommended to implement this proposal and analyze the situation differences to explore effective Reliability Centered Maintenance.

REFERENCES


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